Experimental studies of inputting data using numerical keypads: A Review*

Xunbing Shen
Institute of Psychology, Chinese Academy of Sciences
Graduate University, Chinese Academy of Sciences
Beijing, 100101,China
shenxb@psych.ac.cn

Xiaolan Fu and Changxu Wu
Institute of Psychology, Chinese Academy of Sciences
Beijing, 100101,China
wucx@psych.ac.cn

***Abstract* – In the field of Human-Computer Interaction, there is a basic but important device—numerical keypads, on which was received relatively little focus because of being an auxiliary input device. This literature completely reviewed the experimental studies of numerical keypads, including layout, placement and inputting method, and keypad specification.**

Index Terms* – *Numerical keypad, data inputting, layout, placement, specification.

I. INTRODUCTION

Standard computer keyboards all include a numeric keypad, which is right to the alpha-numeric keyboard. There is little research on it because it is an auxiliary input device. But, indeed, the numeric keypad is useful and important in many tasks and the input error would result in some harmful consequence. For example, for the field of accounting and cashiering (e.g. bank), inaccurate data entry made tax errors, poor management decisions, and incorrect payments. In research work settings, inaccurate data entry introduced random error to datasets and could reduce the reliability, power, and effect sizes[1].

II. THE EFFECT OF LAYOUT OF NUMERIC KEYPADS ON PERFORMANCE

The arrangement of letters or numbers on keyboard is important for research, theory, debate, contests and patent applications[2]. Many layouts, such as The Standard (QWERTY) Layout, The Dvorak Simplified Keyboard Layout, were investigated extensively. On the other hand, though the numeric keypad layout is of importance, there are few studies aimed to investigate the arrangement of keys on a numeric keypad. The first study might be the one conducted by Lutz and Chapains in 1955[3], in which 100 subjects indicated their preference of the configurations of numeric keys. Lutz and Chapains found the most preferred patterns of keys layout
is the so called TEL layout-- the numeric keys were arranged in ascending order from left to right, and top to bottom, as on a pushbutton telephone(see Figure1 panel A). Another often used keys layout is ADD layout, which arranged keys in ascending order, left to right, and bottom to top with zero at

Fig 1. Example of two keypad layouts, panel A is the TEL layout, and panel B is the ADD layout.

the middle-top or at the middle-bottom (see Figure 1 panel B).

To objectively compare the subjects' performance with different numeric keypad layout, Deininger, R. [4] tested sixteen different arrangements, they found only small differences in rate and errors among the 16 layouts. The cause of this might be the subjects who were all the employee at Bell Telephone Laboratories. Conrad and Hull[5] had conducted an experiment which used different numeric keypad with distinct keys arrangements and had subjects enter random eight-digit number material, which standardized the input material. They found that the TEL layout (with zero key in the center of the bottom row) was superior with fewer errors and greater rate when subjects were entering the numbers.

In 1993, Straub and Granaas[6] investigated the preference of layout of numeric keypad under the presence of different tasks, and found that the participants prefer TEL layout to ADD layout when typing telephone number. The participants, contrast to the former results, preferred the ADD layout to TEL layout when executing mathematical calculations. So their results suggested that the preference to layout of numeric keypad might task-dependent and could result in task-specific performance differences.

In 1996, Marteniuk, R.G. et al. [7] studied the performance with keypad-specific tasks and purposely investigated the placement of 10th key, the zero. They found that there is no significant difference between the TEL and ADD layout. But the location of key zero had an effect on

* This work is partially supported by grants from 973 Program (2011CB302201) and the National Natural Science Foundation of China (90820305).
Correspondence concerning this article should be addressed to Changxu Wu, E-mail: wucx@psych.ac.cn.

performance, which is better when key zero was at the top of TEL layout and at the bottom of ADD arrangement than when zero was in other place. According to the previous research, Marteniuk, R.G. et al. proposed that TEL layout should be the choice for a universally adopted layout.

It is worth noting that numeric data entry could use two forms, one is using the numeric keys at the top of QWERTY keyboard and the other is using the numeric keypad on the right of the traditional keyboard. Research had shown that participants entered numeric data more quickly when using the numeric keypad than when using the keys at the top of the keyboard[8].

III. THE EFFECTS OF PLACEMENT AND INPUTTING METHOD OF STANDARD NUMERIC KEYPAD ON PERFORMANCE OF DATA ENTRY.

A. The effects of inputting methods on the performance of data entry

Different data entry methods might have distinct influences on the errors and rate of data entry. There are two main methods in numerical data entry; one is the method of inputting data with visual checking, and another is the method of inputting by listening.

Burns, S.S. et al.[1] found there was high accuracy and less errors using traditional numeric keypad when participants were asked to visually compare the data to the values they had entered.

B. The influences of placement of numeric keypad on data entry

There were a number of studies investigated the physical reconstruction and modification of a keyboard—split keyboard[2]. The split geometry keyboard could trace its history back to 1920s and began to be broadly commercially available in the early 1990s[9]. By now the split keyboard was the number-one selling keyboards among the entire keyboard sold in the U.S. retail market.

Now there are some vertical-split keyboards that could prevent the hand from Repetitive Strain injuries by facing the hands inward toward one’s body (see Figure 2).

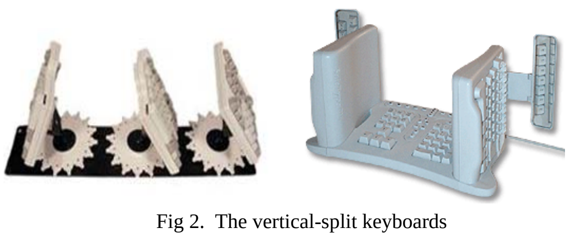

Fig 2. The vertical-split keyboards

These vertical-split keyboards could be consistent with the ergonomic principle. Comparing the vertical-split keyboards to the traditional flat keyboards, some researchers [10-11] had found that the attributes of the former, such as comfort, reduced pain, is better than the latter by surveying. There were some experimental studies about the performance of data entry using the split or vertical-split keyboards [10-12]. To the numeric keypad when standing vertically, however, there is also no study focusing on the performance of data entry.

C. The effects of keypad slope on data entry

Back to some three decades, the slope of keyboards became a matter of debate when the former West Germans announced their requirement for low-profile (30 mm) keyboards having a slope of no more than 15 degrees, enforcing this since January 1, 1985. The cause of the considerations behind the law lay in the pursuit of long-term comfort and avoidance of muscular strain.

What is the best keypad slope (maximizing speed, minimizing errors and most comfortable) for data entry? In 1988, America Human Factors and Ergonomics Society published ANSI/HFS 100-1988 standard, which recommended providing a keyboard slope range from 0 to 25 degrees, and preferably limited to the range of 0 to 15 degrees.

The question above become more and more important nowadays, there are many situations in which numerical keypad work as a mainly data inputting means and could not be placed flatly as usual, such as in hospital, in door security system, and automated teller machines. Many researchers had paid many attentions to the alphanumeric keyboard (see following table1), however there is little, to our knowledge, research focusing on the topic of numeric keypad slope.

TABLE I
THE SUMMARY OF STUDIES ON THE SLOPE OF ALPHANUMERIC KEYBOARD

study	Keyboard	Slope degree	Slope(s) with significant effect on accuracy	Slope(s) with significant effect on inputting speed	Comfort assessment/preferred slopes
Scales and Chapanis(1954)	Keysets used by long-distance telephone operator	0,5,10,15, 20,25,30, 40	No	No	All prefer >0 Half prefer 15-25 degree
Galitz (1965)	computer keyboard	9,21,33	No	No	21 *
Emmons and Hirsch (1982)	IBM 30 mm keyboard	5,12,18	No	Yes (slope12,18 are faster)	18>12>5 (all were uncomfortable)
Miller and Suther (1981 ; 1983)	keyboard	14 - 25 Mean：18	N/A	N/A	slope be adjustable up to 20 degree **
Suther and McTyre (1982),	keyboard	5,10,15,25	No	No	10 and15. One person like 25 degrees***
Abemethy (1984), Abernethy and Akagi, (1984)	keyboard	8,12	N/A	N/A	Average 16.1 degrees
Najjar, Stanton, and Bowen (1988)	keyboard	-15,0,+15	No	Yes(significant interaction between keyboard height and slope)	0,-15

(Continued)

TABLE I
THE SUMMARY OF STUDIES ON THE SLOPE OF ALPHANUMERIC KEYBOARD
(Continued)

study	Keyboard	Slope degree	Slope(s) with significant effect on accuracy	Slope(s) with significant effect on inputting speed	Comfort assessment/preferred slopes
Hansen (1983)	Small keypad in aircraft cockpits,	0,15,35	No	No	15
Burke, Muto, and Gutmann (1984)	keyboard	11	No	No	N/A
M.Woods andK.Babski-Reeves, (2005)	keybord	7,0, -10, -20,-30	N/A	Yes(-10 faster)	No consistent results.
Gerard P. van Galen, Hanneke Liesker, Ab de Haan, (2007)	A newly designed vertical, split keyboard (Yogi type keyboard)	90	Yes	Yes	Seven out of nine prefer the vertical keyboard

Note. Adapted from "Keys and keyboards," by Lewis, J., Potosnak, K., and Magyar, in Handbook of human-computer interaction (2nd ed.), M.G. Helander, T.K. Landauer, Editor. North-Holland: Amsterdam. p. 1285–1316.

* The author suggest a slope adjustable between 10 and 35 degrees

** They recommended that keyboard slope be adjustable up to at least 20 degree (with 25 degrees being better) to suit individual preferences.

*** they found that taller people and those with long hands tended to like the lower slope, but short people and those with short hands liked the steeper slope. Suther and McTyre recommended that keyboards have an adjustable slope between 10 and 25 degrees.

IV .THE EFFECTS OF SPECIFICATION OF NUMERIC KEYPAD ON RATE AND ERRORS OF DATA ENTRY

For traditional keyboard, its physical features, such as height, slope, profile (dished, stepped, or flat), size, shape and key force, were studied extensively[2]. The physical features and technical specifications of numeric keypad might have an effect on errors and rate of data entry. However, there was relatively little research focusing on this issue.

In 1960, Deininger firstly tested a 10-key numeric keypad with different key sizes and shapes, and found the time of keying and the accuracy had improved when the key size increased from 9.5 to 12.7mm [2]. Thirty years later, in 1991, Loricchio and Lewis investigated three commercial calculators with different key spacing and key size. There was no significant main effect of accuracy for the three calculators, but they found the keying speed were more fast when the key size was 10×10mm than that when the keys was 14×10 mm.

A function named "force/displacement function" describes the force and the travel distance of a key when pressing it. Research has found that the amount of key force and travel distance of a key did not affect performance[4].

The tactile or kinesthetic feedback is important for the typists' performance. Barrett and Krueger[13] compared performance and preference of two types of keyboard, one is the traditional keyboard, and the other is piezo-electric keyboard without tactile feedback. They found that participants' performance were significantly higher on the conventional keyboard. The same might be true for the numeric keypad.

The size of numeric keypad could affect the performance of data entry. Loricchio and Lewis[14] compared the performances among a standard-size numeric keypad, two keypads that had reduced center-to-center key spacing (one of them reduced the key spacing, and the other reduced both key size and spacing). They found that skilled keypad operators typed numbers faster with standard keypad over the other two reduce-size numeric keypads.

V. CONCLUSIONS

The experimental studies of numeric keypad were relatively fewer. We might generalize the results got from the studies of keyboard to the numeric keypad. But it is unclear whether or not, or to what extent, the principles obtained by the studies of traditional keyboard could be applied to the numeric keypad.

Because there are rapidly increasing aging populations, we are confronting a new set of challenges for human factors design. In the future, we should pay more attention to the age difference of performance with the numeric keypad. Now some researchers are set to concern with this issue[15].

REFERENCES

[1] Shatoyia S. Burns, G.J.F., Heidi A. Johanson, Brian Brehman & Kimberly A. Barchard, Data Entry Accuracy and Comfort with the Number Pad. , in Association For Psychology Sciences Annual Convention. 2009, University of Nevada, Las Vegas: San Francisco, CA.

[2] Lewis, J., Potosnak, K., & Magyar, R. , Keys and keyboards, in Handbook of human-computer interaction(2nd ed), M.G. Helander, T.K. Landauer, Editor. 1997, North-Holland: Amsterdam. pp. 1285–1316.

[3] Lutz, M. and A. Chapanis, Expected locations of digits and letters on ten-button keysets. Journal of Applied Psychology, 1955. 39(5): pp. 314-317.

[4] Deininger, R., Human factors engineering studies of the design and use of pushbutton telephone sets. Bell System Technical Journal, 1960. 39: pp. 995-1012.

[5] Conrad, R. and A. Hull, The preferred layout for numeral data-entry keysets. Ergonomics, 1968. 11(2): pp. 165-173.

[6] Straub, H. and M. Granaas, Task-specific preference for numeric keypads. Applied Ergonomics, 1993. 24(4): pp. 289-290.

[7] Marteniuk, R.G., C.J. Ivens, and B.E. Brown, Are there task specific performance effects for differently configured numeric keypads? Applied Ergonomics, 1996. 27(5): pp. 321-325.

[8] Mitchard, H. and J. Winkles, Experimental comparisons of data entry by automated speech recognition, keyboard, and mouse. Human factors, 2002. 44(2): pp. 198.

[9] Rempel, D., The Split Keyboard: An Ergonomics Success Story. Human factors, 2008. 50(3): pp. 385.

[10]Muss, T. and A. Hedge. Effects of a vertical split-keyboard on posture, comfort and performance. 1999: Human Factors and Ergonomics Society.
[11]Van Galen, G., H. Liesker, and A. de Haan, Effects of a vertical keyboard design on typing performance, user comfort and muscle tension. Applied Ergonomics, 2007. 38(1): pp. 99-107.
[12]Khalaf, T., et al., Effects of three keyboard designs on wrist and forearm postures and typing task performance. Occupational Ergonomics, 2007. 7(2): pp. 115-123.
[13]Barrett, J. and H. Krueger, Performance effects of reduced proprioceptive feedback on touch typists and casual users in a typing task. Behaviour & Information Technology, 1994. 13(6): pp. 373-381.
[14]Loricchio, D.F., Lewis, J. R. User assessment of standard and reduced-size numeric keypads. in Proceedings of the Human Factors Society 35th Annual Meeting 1991. San Francisco, CA.: Human Factors Society.
[15]Chung, M.K., et al., Usability evaluation of numeric entry tasks on keypad type and age. International Journal of Industrial Ergonomics, 2010. 40(1): pp. 97-105.